

DOCUMENT RESUME

ED 157 629

PS 010 056

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TITLE Behavioral Contrast in Infants.
PUB DATE 78
NOTE 26p.; An abbreviated version of this paper was presented at the Annual Meeting of the Midwestern Psychological Association (50th, Chicago, Illinois, 1978)

EDRS PRICE MF-\$0.83 HC-\$2.06 Plus Postage.
DESCRIPTORS Cues; *Infant Behavior; *Infants; *Motor Reactions; Peer Groups; Reaction Time; *Reinforcement; Research; *Response Mode; Self Control; *Visual Stimuli

ABSTRACT

This study used the behavioral contrast paradigm to assess the excitatory and inhibitory capabilities of young infants. Behavioral contrast is described as the phenomenon whereby the rates of responding in the presence of two stimuli, both of which were previously associated with reinforcement, change in opposite directions when only one of them becomes associated with the reinforcer. In the study, 20 infants 93 to 120 days old were trained on 2 days to produce rotation of an overhead mobile via right footkicks in the presence of two visual cues. After achieving a criterion of stable responding on a third day, one group of infants received alternating 30-second periods of reinforcement and nonreinforcement with one cue signalling each component of the reinforcement schedule. These infants dramatically increased their rate of response when reinforcement was available; however, the expected corresponding response decrease during nonreinforcement periods was not evidenced. Control infants, who continued to receive continuous reinforcement throughout the third-day session, did not change their rate of response from criterion. All infants returned to a similar response rate on a fourth day when reinforcement was continuously available for both groups. Results indicated that young infants manipulated their visual environments in relation to changes in reinforcement density from previous reward experiences. Finally, the ability of young infants to rapidly inhibit previously reinforced motoric responses was discussed. (Author/CM)

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Behavioral Contrast in Infants

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Abstract

The excitatory and inhibitory capabilities of young infants were assessed with the behavioral contrast paradigm. Twenty infants received 2 days of mobile reinforcement for right footkicks in the presence of 2 visual cues. After achieving a criterion of stable responding on a third day, one group of infants received alternating 30-sec periods of reinforcement and nonreinforcement with 1 cue signalling each component of the reinforcement schedule. These infants dramatically increased their rate of response when reinforcement was available, however, the expected corresponding response decrease during nonreinforcement periods was not evidenced. Control infants, who continued to receive continuous reinforcement throughout the Day-3 session, did not change their rate of response from criterion. All infants returned to a similar response rate on a fourth day when reinforcement was continuously available for both groups. The results were discussed in terms of the ability of young infants to rapidly inhibit previously reinforced motoric responses.

Behavioral Contrast in Infants

It is well known that young infants, even newborns, are capable of discrimination learning. For example, Siqueland and Lipsitt (1966) reinforced newborns for right head-turns in the presence of one auditory stimulus (S+) but not in the presence of another (S-). Discrimination learning was evident in this study by a reliable increase over trials in the percent of right head-turns to the positive stimulus. Responding in the presence of the negative stimulus did not change. Following discrimination acquisition, the contingencies associated with each auditory stimulus were reversed such that reinforcement was now provided only for head-turns to the original negative stimulus (now the S+). Successful reversal was evident only insofar as the response to the new S- (the former S+) returned to its baseline level. Responding to the new S+ did not change. As pointed out by the authors, the decrease in S- responding may have been due to the combined effects of extinction and satiation.

Apart from its demonstration of discrimination learning in the newborn, one might interpret the results of Siqueland and Lipsitt (1966) as providing evidence for the existence of inhibitory control in the newborn. Specifically, the lack of increased responding to S- could be taken as evidence for the inhibition of the right head-turn response. However, Reese and Lipsitt (1970) have cautioned against such a conclusion reasoning, as did Jenkins (1965), that the obtained discrimination could have resulted solely from the excitatory control of S+. Siqueland and Lipsitt (1966) provided support for such an interpretation by demonstrating that the increase in ipsilateral head-turning to S+ was accompanied by increased contralateral responding to S-. In addition, both Luria (1961) and White (1965) have theorized that both infants

and young children are deficient in the ability to inhibit motoric responses. Fagen (1977), using a discrimination learning set task, found that this inhibitory control had begun to develop in 10-mo-old infants but was incomplete at that age.

A recent study by Kalnins and Bruner (1973) added support to the hypothesized lack of inhibitory mechanisms during infancy. In one condition, 5- to 12-wk-old infants were required to suck on a nipple to maintain the presence of a visual reinforcer. In a second condition, same aged infants were required to inhibit sucking to receive the equivalent reinforcement. The results indicated that while infants in the first condition reliably increased their rate of sucking above baseline, those in the second condition were incapable of the response reduction required by the contingency. Following this training, infants in these two conditions were switched to the opposite contingencies. Infants now required to inhibit sucking for reinforcement showed a decrease in response rate, but did not fall below baseline. Surprisingly, infants now required to suck for reinforcement did not demonstrate a corresponding increase in suck rate. Thus, the infants in this study were able to increase, but not decrease, their rate of response to produce reinforcement.

The present study represented a further investigation of the inhibitory and excitatory capabilities of the young infant using the behavioral contrast paradigm (Reynolds, 1961). Briefly, behavioral contrast is the phenomenon whereby the rates of responding in the presence of two stimuli, both of which were previously associated with reinforcement, change in opposite directions when only one of them becomes associated with the reinforcer. In operant terminology, behavioral contrast results when a subject is shifted from a multiple schedule where both components are reinforced (e.g., mult VI5 VI5) to

one in which only one component is reinforced (e.g., mult VI5 EXT). This paradigm was chosen because the phenomenon of contrast is believed to result from active response inhibition (Halliday & Boakes, 1972) resulting from the emotional effects of non-reinforced responding (Terrace, 1966). That young infants are capable of demonstrating emotional responses when the reinforcing environment is altered has been demonstrated (Fagen & Rovee, 1976, Experiment 2).

In the present study, infants were trained on 2 days to produce rotation of an overhead mobile via right footkicks in the presence of a red and green cue. Following a return to a stable level of responding on a third day, half of the infants were switched to a contingency whereby responses in the presence of only 1 cue were reinforced. The remaining infants continued to receive reinforcement throughout Day 3. Finally, on Day 4, all infants again received reinforcement in the presence of both cues.

Method

Subjects

The final sample consisted of 20 healthy and apparently normal infants ranging in age from 93 to 120 days with a mean age of 105.80 days ($s = 8.69$). Subjects were recruited from birth announcements in local newspapers. Infants were randomly assigned to an experimental or control group with the stipulation that each group contain an equal number of males and females. Four additional subjects (2 males and 2 females) were excluded from the final sample due to crying.

All infants were tested in their home cribs during their typical play or alert periods. This period varied from infant to infant but remained constant for a given infant.

Apparatus

The mobile apparatus consisted of an overhead metal suspension bar secured to an adjustable floor stand such that the end of the bar was centrally located over the crib. A 15 x 9 cm black plastic box was secured to the end of the bar. A 15 RPM Hurst motor was mounted inside of this box such that the motor shaft protruded through the center. A commercially available 5-object wooden mobile (Knickerbocker Toy Co., Model No. 3429), modified so that its components dangled on fine string lines only 9 cm below the ends of its intersecting arms and center, was secured to the end of the shaft. Two 24V pilot lights (one red and the other green) were mounted 2 cm above and 3 cm to the left and right of the shaft.

Procedure

All infants were tested on 4 consecutive days. On each day the infant was placed supine in his or her crib such that the mobile components were 30 cm above the crib mattress and directly above the infant's chest. On Day 1, all infants received a 2-min baseline phase during which the mobile was in view but nonresponsive. This was immediately followed by an 8-min acquisition phase where right footkicks produced a 1.6-sec rotation (approximately $\frac{1}{4}$ turn) of the mobile. The pilot lights were alternately lighted every 30-sec with the one illuminated at the outset of the Day-1 session counterbalanced across subjects. On Day 2, all infants received an additional 8 min of acquisition training with the pilot lights alternating as before. Day 3 also began with this acquisition training but continued only until individual responding for 4 successive 30-sec periods equalled or exceeded the mean response rate of that subject's final 8 30-sec periods (last half) of Day 2 training, or for 8 min, whichever occurred first. Following this criterion, experimental

subjects continued to receive alternating 30-sec presentations of each light, however, footkicking only in the presence of the light illuminated during the first postcriterion 30-sec period was reinforced. This procedure of alternating 30-sec reinforced and nonreinforced periods lasted for an additional 8 min. In other words, experimental subjects were reinforced on a mult CRF CRF schedule for Days 1 and 2 and until criterion was reached on Day 3, after which they were reinforced on a mult CRF EXT schedule. Control subjects, who were also brought to the same criterion, continued to receive reinforcement on a mult CRF CRF schedule for 8-postcriterion minutes. On Day 4, all infants received 8 min of acquisition with responses in the presence of both lights reinforced (i.e., mult CRF CRF) followed by 4 min of extinction during which the mobile was in view but nonresponsive (i.e., mult EXT EXT). The light illuminated during the first 30-sec period of Day 4 was the same as that during the first 30-sec postcriterion period of Day 3.

The number of right footkicks in each 30-sec period was recorded by a trained observer positioned several feet from the crib and out of direct view of the infant. A kick was defined as a "vertical or horizontal excursion of the right foot that at least partially retraced its original path in a smooth continuous motion" (Rovee & Fagen, 1976, p.4). When this response occurred, the observer depressed a hand-held switch that initiated the reinforcement if the subject was in a reinforcement period. Interobserver reliabilities ranging from 0.97 to 0.99 have previously been reported for this response in a similar procedure using the same observer (Fagen & Rovee, 1976; Rovee & Fagen, 1976).

Results

Days 1 and 2

The first analysis of the footkick data was designed to determine when,

on Day 1, the infants showed a reliable increase in responding above baseline. To do this, the data for the 30-sec periods were combined into successive 2-min blocks and subjected to a 2 (Sex) x 5 (Blocks) analysis of variance with repeated measures on the Blocks factor. Because the covariance matrix for the repeated measure did not have compound symmetry, the degrees of freedom for all of the F statistics were adjusted by the Greenhouse-Geiser correction (Winer, 1971). This analysis yielded a reliable main effect of Blocks [$F(1, 18) = 21.42, p < .001$] which was described by a highly significant linear trend [$F(1, 18) = 85.05, p < .001$] accounting for 99% of the variability in the Blocks main effect (see Figure 1). No other main effects or interactions achieved reliability. A Dunnett's t -test (Winer, 1971) was used to determine when reliable conditioning had occurred. This test indicated that the infants kicked reliably above baseline beginning at the second acquisition block [$t(5, 18) = 4.54, p < .005$].

Insert Figure 1 about here

The Day-2 acquisition data were also combined into successive 2-min blocks to determine if any changes occurred in acquisition training across the 2 days. Specifically, it was of interest to determine (a) if the mean rate of responding decreased significantly between the last acquisition block of Day 1 and the first of Day 2, and (b) if the terminal Day-2 response level was above that of Day 1. A 2 (Sex) x 2 (Day) x 4 (Blocks) repeated measures analysis of variance was conducted across the reinforcement blocks of the 2 days. Again, the assumption of compound symmetry was not met and the Greenhouse-Geiser correction was employed. The main effect of Day was significant [$F(1, 18) = 4.49, p < .05$], reflecting a higher level of overall responding on Day 2 as

compared to Day 1. In addition, the main effect of Blocks was also reliable [$F(1, 18) = 16.64, p < .001$]. However, the interaction of these two variables was not significant [$F(1, 18) < 1$]. A Newman-Keuls test (Winer, 1971) revealed that neither the apparent drop in responding from the end of Day 1 to the beginning of Day 2, nor the apparent increase in terminal responding between the 2 days, were reliable. Thus, responding reached a stable, above-baseline level on Day 1 and remained there throughout the 2 training days.

Days 3 and 4

The analyses of the Day 3 and 4 data sought to determine (a) if reliable changes in responding occurred on Day 3 in the experimental group as a function of the shift in reinforcement condition (i.e., to a mult CRF EXT schedule), and (b) if the experimental and control infants returned to a similar response pattern on Day 4 when the contingency shift was removed (i.e., a return to the mult CRF CRF schedule for experimental infants). Both raw and change scores from the preshift criterion were analyzed, but in every analysis the results were similar, and so only the change scores will be presented.

Day 3. The Day-3 data were subjected to a 2 (Sex) x 2 (Group: Experimental, Control) x 2 (Stimulus: S+, S-), x 8 (30-sec Period) analysis of variance with repeated measures on the Stimulus and Period factors.¹ This analysis yielded a reliable main effect of Stimulus [$F(1, 16) = 25.66, p < .001$] resulting from an overall increase in responding from criterion for S+ and a decrease for S-. The interactions of Group x Stimulus [$F(1, 16) = 23.88, p < .001$] and Stimulus x Period [$F(7, 112) = 3.82, p < .001$] were also reliable. Of major importance was the three-way interaction among these variables (i.e., the Group x Stimulus x Period interaction) which was also significant [$F(7, 112)$]

= 2.82, $p < .01$, see Figure 2]. To determine the nature of this interaction, separate Group x Period analyses of variance were conducted for S+ and S-. These were followed by simple-effects tests to determine if experimental infants evidenced a reliable response increase during S+ and decrease during S- relative to the control infants during the corresponding 30-sec periods. These analyses indicated that while the responding of experimental infants increased dramatically across S+ periods [$F(7, 126) = 3.68, p < .005$] that of control infants did not change [$F(7, 126) < 1$]. Unfortunately, the expected opposite effect did not occur for experimental infants during S-. Here, although the control infants performed as before [$F(7, 126) < 1$], the experimental infants did not reliably decrease their response rates during nonreinforcement periods [$F(7, 126) = 1.77, p < .10$]. Thus, although it appears in Figure 2 that behavioral contrast as typically reported in the animal literature had occurred, these babies only increased their response rates in S+. The typical decrease in S- responding characteristic of this phenomenon did not occur.

Insert Figure 2 about here

Due to the amount of response variability evident across the 30-sec postshift periods, the postshift session was divided in half by averaging the change scores across the first and last 4 S+ and S- periods. This yielded 4 scores for each infant representing the factorial combination of stimulus condition and postshift half (see Figure 3). These were subjected to a 2 (Sex) x 2 (Group) x 2 (Stimulus) x 2 (Half) analysis of variance with repeated measures across the Stimulus and Half factors. As with the analysis across the 30-sec periods, the main effect of Stimulus [$F(1, 16) = 25.14, p < .001$] and the Group x Stimulus [$F(1, 16) = 22.84, p < .001$] and Stimulus x

Half [$F(1, 16) = 7.77, p < .025$] interactions were reliable. In addition, the Group $\times$ Stimulus $\times$ Half interaction was significant [$F(1, 16) = 10.77, p < .005$]. Separate Group $\times$ Half analyses of variance for S+ and S- and tests of simple effects produced results comparable to the data across the 30-sec periods. Specifically, experimental infants evidenced a reliable response increase during S+ [$F(1, 18) = 7.53, p < .05$] but did not decrease their response rate during S- [$F(1, 18) = 2.16, p < .25$]. Control infants did not change their rate of responding ($F_s < 1$).

Insert Figure 3 about here

Day 4. The Day-4 data were analyzed in a manner similar to that of Day 3. The 30-sec period response changes were subjected to a 2 (Sex) $\times$ 2 (Group) $\times$ 2 (Stimulus) $\times$ 8 (Period) repeated measures analysis of variance. This analysis yielded a reliable main effect of Period [$F(7, 112) = 10.49, p < .001$] which was described by a reliable linear increasing trend [$F(1, 112) = 32.02, p < .001$]. In addition, the Stimulus $\times$ Period interaction was significant [$F(7, 112) = 2.74, p < .025$]. This interaction resulted from the fact that the negative change in responding from Day-3 criterion was initially greater for both groups combined under S- than under S+. By the end of Day-4 acquisition, responding under both stimulus conditions had switched to a positive increase over Day-3 criterion with the increase being greater under S- (see Figure 2). No explanation of this finding was apparent.

The data over the 30-sec periods on Day 4 were also divided in half in a manner similar to that of Day 3 (see Figure 3). A 2 (Sex) $\times$ 2 (Group) $\times$ 2 (Stimulus) $\times$ 2 (Half) analysis of variance yielded a reliable main effect of Half only [$F(1, 16) = 10.66, p < .005$]. The interaction of Stimulus $\times$ Half,

predicted from the previous analysis, did not achieve reliability [$F(1, 16) = 4.02, p < .10$].

The final analysis of the Day-4 data ignored the 2 stimulus conditions since all infants were again receiving reinforcement under both stimuli. Here the data from the 8 min of acquisition, as well as that from the 4 min of extinction, were combined into successive 2-min blocks and subjected to a 2 (Sex) x 2 (Group) x 6 (Blocks) analysis of variance with repeated measures on the Blocks factor. As with the analyses of Days 1 and 2, the assumption of compound symmetry was not met and the Greenhouse-Geisser correction was applied to the degrees of freedom. This analysis yielded a main effect of Group [$F(1, 16) = 4.96, p < .05$] resulting from a higher overall response rate in control infants (see Figure 4). In addition, the main effect of Blocks was reliable [$F(1, 18) = 5.01, p < .05$]. Trend analyses conducted across the 6 blocks separately for each group indicated that while the response rate of the control infants was described by a linear increasing trend [$F(1, 18) = 24.52, p < .001$], that of experimental infants was quadratic [$F(1, 18) = 14.81, p < .005$]. Examination of the data (see Figure 4) indicated that the reason for this discrepancy was clear. Only experimental infants produced a decline in responding appropriate for the extinction contingency. Control infants not only failed to diminish their level of responding, but actually showed an increase.

Insert Figure 4 about here

Discussion

The results of the present study indicate that young infants are indeed sensitive to changes in the reinforcing environment. Apparently, when the

consequences of a response become less reinforcing under one stimulus condition, the infant increases his or her response rate in the presence of another stimulus where its consequences remain reinforcing, thereby exaggerating the value of the reinforcer in the latter condition. That this response increase was not directly tied to the temporal parameters of the present experiment was evidenced by the infants in the control group who did not change their response rate after reaching criterion. These data are consistent with other findings on shifts in the magnitude (complexity) of reward (Fagen & Rovee, 1976) and imply that infants do manipulate their visual environments in relation to changes in reinforcement density from previous reward experiences.

It was predicted that the change to a mult CRF EXT schedule of reinforcement on Day 3 would produce an increase in responding during S+ and a corresponding decrease in S-. Although a shift in reinforcement schedule did produce response changes, only the predicted increase in S+ occurred. The lack of response reduction in S- is consistent with other infant data (e.g., Fagen, 1977; Kalins & Bruner, 1973) and may indicate that infants are incapable of rapidly inhibiting previously reinforced motoric responses. In agreement with Luria (1961), young infants who have been reinforced in the presence of two cues may have difficulty overcoming (i.e., inhibiting) the "impulse" to respond to both of them. He postulated that the preverbal child could not gain complete inhibitory control of his or her responses until a "natural self-regulating system" (p. 85) had developed. Thus, for Luria, the main problem in the infant is the lack of appropriate inhibitory mechanisms, the possession of which may be necessary for the complete exhibition of behavioral contrast.

The lack of response reduction in S- leads to the question of whether

or not behavioral contrast, as typically defined, occurred in these infants. Recall that for Terrace (1968), the important aspect of this phenomenon was the decreased responding in S- produced by the change in the response contingency. Bloomfield (1969), however, has claimed that this view of behavioral contrast is open to question. Specifically, Bloomfield proposed that behavioral contrast occurs when "...response rate in one component of a multiple schedule tends to increase when conditions in the other component change for the worse" (p.220). This definition does not imply that the response rate must decrease in S- for contrast to occur in S+. Furthermore, he pointed out that the development of inhibition, and therefore the subsequent response decrease in S-, is but one possible event constituting a "change for the worse." A simple reduction of reinforcement frequency may be an equally powerful event. In other words, the response reduction typically found during S- is neither a necessary nor a sufficient condition for contrast to appear.

In a more recent theoretical account of behavioral contrast, Halliday and Boakes (1972) have also questioned the necessity and sufficiency of reduced S- responding while still relying on the concept of active inhibition. They proposed a "response inhibition rebound" mechanism whereby the omission of reinforcement in one component of the schedule leads to the establishment of an inhibitory process which has the effect of suppressing responses. In a situation where one stimulus (i.e., S-) is associated with the inhibition of a learned response, a "rebound effect" occurs in the presence of another stimulus (i.e., S+) where the learned response is still reinforced. This, according to Halliday and Boakes, dramatically increases the response rate in the presence of the continually reinforced stimulus. Based on the increased

responding in S+, it appears that the infants of the present study detected that responding in S- was ineffective (i.e., the rebound effect occurred in S+) but either lacked the necessary inhibitory process to decrease responding in S- or else the process had only begun to develop by the end of the Day-3 session. Alternatively, the increased responding in S+ could be interpreted as evidence for an inhibitory process in these infants. It may be incorrect to assume that the presence of appropriate inhibitory mechanisms in the young infant can only be assessed by the type of response reduction characteristic of inhibition in infrahuman organisms. The nature of the behavior produced by the inhibitory process in young infants may be completely different and may even be characterized by a stable response rate.

Figure Captions

Figure 1. Mean footkick rates of 20 infants over the 2 days of training in 2-min blocks. Block 1 on Day 1 represents baseline; all remaining blocks represent reinforcement periods.

Figure 2. Mean footkick change of experimental and control groups from criterion in 30-sec trials of S+ and S-.

Figure 3. Mean footkick change of experimental and control groups from criterion over the first and second halves of the Day-3 and Day-4 sessions. Each half represents the mean change from criterion of 4 successive 30-sec trials.

Figure 4. Mean footkick rates of experimental (E) and control (C) infants in 2-min blocks. Blocks 1-4 represent reinforcement periods while blocks 5 and 6 represent extinction.

Footnotes

An abbreviated version of this paper was presented at the 1978 meeting of the Midwestern Psychological Association, Chicago, Illinois. Requests for reprints should be sent to Jeffrey W. Fagen, Department of Psychology, Northern Illinois University, DeKalb, Illinois 60115.

¹The use of the S- notation for the control group may be misleading in that these infants received reinforcement when either stimulus light was illuminated. Its use here is intended to reflect the 30-sec periods when, if these babies had been assigned to the experimental group, nonreinforcement would have occurred.

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